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633

# United States Department of Agriculture,

## OFFICE OF EXPERIMENT STATIONS—Circular No. 55.

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# THE RELATION OF THE NATURAL SCIENCES TO AGRICULTURE IN A FOUR-YEAR COLLEGE COURSE.[1]

The more definite formulation of courses of instruction in agriculture, the division of these courses according to the several branches of the science of agriculture, and the consequent specialization of the courses due to the employment of an increased force of experts in various agricultural subjects, have already led to a considerable reorganization of faculties and courses in our agricultural colleges. This movement is continuing and will further develop with the increase of the resources and equipment of the agricultural departments of these institutions. One effect of this movement has been to change the relation of the natural sciences to agriculture in the scheme of instruction in the agricultural colleges. As long as agriculture was taught almost wholly on a practical basis and without much regard to its pedagogical formulation, the teachers of the natural sciences were called upon not only to develop the relations of these sciences to agriculture in their courses of instruction, but to give instruction in strictly agricultural subjects, and this was done to a considerable extent, especially in chemistry and botany. Out of this grew a series of text-books and manuals in which the general principles of these sciences were more or less extensively combined with statements of their relations to the theory and practice of agriculture. Thus we have books on agricultural chemistry, agricultural botany, agricultural physics, etc. The preparation of such books was a very useful work. They helped to turn the attention of scientists to the importance of the problems of agriculture and thus led to the further investigation of these problems; they brought together many facts and principles out of which in large measure the science of agriculture itself is now being constructed. But this method of procedure, as we can now see, had also some unfortunate results from which we are seeking to escape through the more thorough formulation of the science of agriculture and of courses based thereon, and the readjustment of the courses in the natural sciences to meet this new condition of agricultural pedagogy.

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[1] The eighth report of the committee on methods of teaching agriculture of the Association of American Agricultural Colleges and Experiment Stations, which was presented to the convention of the Association held at Washington, D. C., November 17–19, 1903. For previous reports see U. S. Dept. Agr., Office of Experiment Stations Buls. 41, p. 57; 49, p. 29; 65, p. 79; 76, p. 39; 99, p. 86; 115, p. 59; 123, p. 45, and Circs. 32, 37, 39, 41, 45, and 49.

One result of the prolonged study of the relations of science to agriculture was to lead both teacher and student too far afield in the pursuit of problems which, though important scientifically and even economically, had too remote connection with agriculture itself to make it worth while for the student whose aim was to be a master of the theory and practice of agriculture to follow after them. Thus, for example, agricultural chemistry developed a system of analysis of fertilizers, feeding stuffs, and adulterated products which in the minds of many teachers came to be so prominent a part of this branch of chemistry that it often assumed an undue importance in the general agricultural courses in our colleges. Now we shall always need expert analysts of fertilizers and feeding stuffs, and special courses for the training of those experts should be offered in our agricultural colleges. But these should be clearly differentiated from the courses intended to lay the foundations for the scientific study of agriculture. Under the old system the emphasis was often laid so much on analytical work that the colleges produced many analysts and but few agricultural experts. So in botany it is easily possible, for example, to lay so much stress on studies of fungi and bacteria, or grasses, that the students are led to strive to become experts in vegetable pathology or agrostology. It is true we need many more such experts, but. nevertheless, it should not be the object of botanical studies underlying the general course in agriculture to aim at the training of pathological experts, or agrostologists, or any other kind of botanical experts. While botanical experts and agricultural experts may for a time profitably study botany together their paths should soon diverge, and this must be kept in mind by teachers of botany.

Another unfortunate result of the old arrangement of courses in our agricultural colleges was that the study of the general principles and outlines of the various natural sciences was often unwisely abridged in order to give more attention to their economic applications. This has perhaps not been so much the fault of the science teachers as of the managers of the agricultural colleges. The attempt to create a very practical atmosphere in these institutions has often led to great disregard of established pedagogical principles in the teaching of the complex subjects relating to agriculture and other arts. Nothing is more firmly established in pedagogical science than the principle that, before proceeding to the study of complex problems, the pupil should become acquainted with the elementary facts and principles involved in the solution of these problems. It is also very generally agreed that an outline study of a general subject which will enable the pupil to have some comprehension of the subject as a whole and the relations of its different parts, should precede detailed study of special topics included in this general subject. Thus it is best both practically and pedagogically that the boy in the graded schools should be taught an outline of the history of the United States. He will thus acquire a certain amount of information which will be useful to him if he goes out into life from the graded school, and he will also have laid the best foundation for such special studies of United States history as he may have opportunity to pursue in higher courses of instruction. In like manner in the natural sciences there should be a sufficient period of general study before special topics are taken up, and the abridgment of this preliminary course throws the future course of the student out of pedagogical balance.

The general readjustments of science teaching which are demanded by the present development of our agricultural colleges are, therefore, first the more thorough teaching of the foundations of the natural sciences; secondly, the clearer differentiation of the courses in natural science associated with the courses in agriculture from those which are intended for the training of experts in various economic specialties related to agriculture; and, thirdly, the separation from the science courses of those subjects which may be more appropriately taught by the instructors in the various branches of agriculture itself. From the nature of the case it is obvious that the details of these readjustments can be worked out only as the result of many experimental efforts and long discussion of the practical and pedagogical points involved. The evolutionary forces which are to result in the elaboration of more perfect and satisfactory courses of instruction in agriculture are already at work in our agricultural institutions and they will continue to work for an indefinite period. It has seemed, however, to your committee that at this juncture it would be helpful to call attention to some of the general factors of this evolution and even to suggest a somewhat definite mode of procedure to secure the sought-for ends. In this, as in other lines of its work, the committee has assumed that it would be more useful to present a definite scheme rather than general suggestions. This is done with the understanding, as heretofore, that the committee is not seeking to establish dogmas or write prescriptions, but only to furnish a definite basis for discussion. It is the more encouraged to continue efforts in this line because it is convinced that, as the result of its previous efforts, the movement for the betterment of courses of instruction in our agricultural colleges has been materially aided, though no institution has adopted in detail the programme laid down in the reports of this committee.

As the basis of our presentation of a scheme of science teaching for a four-year college course in agriculture, we take (1) the standard entrance requirements laid down in the report of your committee on entrance requirements as published in Bulletin No. 41 of the Office of Experiment Stations; (2) the general outline of the college course as made by that committee and our committee and published in Circular No. 37 of the Office of Experiment Stations; and (3) the syllabi of courses in the different branches of agriculture as laid down in the reports of this committee published in Circulars Nos. 39, 41, and 45 of said Office.

The standard entrance requirement scheme has been taken, rather than the abridged scheme presented by the entrance requirement committee, because in our judgment there can be no satisfactory arrangement of college courses in agriculture until the students admitted to the college courses have had suitable preparation in secondary schools. Within the past few years there has been a wonderful development of the high schools in all parts of our country and there has been set on foot a movement for the establishment of secondary schools and courses especially adapted to the requirements of our agricultural communities. The agricultural colleges should encourage this development of secondary education in many ways. But they should do so especially by differentiating their college courses more distinctly from secondary courses, and putting their college courses on a sufficiently high basis to make the bachelor's degree from an agricultural college represent an education of as high a grade as a bachelor's degree from any other college. For this purpose the standard entrance requirement scheme referred to above is none too high. This provides for at least a year's instruction in some natural science. It is believed by your committee that ordinarily an elementary course in physics or chemistry in the high school will best lay the foundation for further science study. In the scheme herewith presented we selected physics as the science to be taught in the high school as the preliminary to science study in the college course in agriculture.

In the general scheme of the four-year college course in agriculture presented herewith, we have first provided for courses in general physics and chemistry on the assumption that these would naturally precede the study of plants and animals, whether in a general way under the head of botany, physiology, or zoology, or in a special way under the different branches of agriculture. Some knowledge of physics and chemistry is also essential to a proper understanding of even the elements of meteorology and geology, as provided for in this course. Botany has been so placed as to run along with agronomy, and physiology and zoology with the more scientific presentation of zootechny.

While we believe it would be well for the agricultural student in his undergraduate work to take all of the subjects included in the scheme as here outlined, yet we have recognized the demand for an earlier specialization of agricultural work by so arranging the course that in senior year at least some studies may be substituted for those laid down in our scheme. For example, if the student is aiming to be a plant expert he may omit veterinary science and take more of applied botany or horticulture, or specialize in agronomy as far as additional courses in these subjects are offered in the institution he attends. In a similar way the student devoted to animal industry may substitute special studies along this line for the horticulture and forestry.

Agricultural experts can not, however, expect that any properly adjusted undergraduate course will fully meet their needs for training along their chosen lines. Persons who expect to enter positions in our Department of Agriculture, experiment stations, or agricultural colleges should attain at least the master's degree. And erelong the doctor's degree will be a prerequisite to entrance on the career of agricultural teacher or investigator in our colleges and universities and the National Department of Agriculture.

In outlining the courses in the various sciences the purpose has been to indicate in a general way the topics which may properly be included in such courses, taking into account the time limitations and what will be taught under the head of agriculture. The arrangement of these topics and the emphasis to be laid on each of them will, of course, vary with the teacher as well as the equipment and other conditions existing in particular institutions. Our effort has been chiefly to so present this matter as to indicate how the science teaching may be differentiated from and at the same time related to the teaching of agriculture in a college course.

In arranging this scheme the committee has had the assistance of the expert officers of the Office of Experiment Stations and of Prof. G. P. Merrill, the geologist of the Smithsonian Institution.. Text-books and specialists in a number of different lines have also been consulted. As the result of a conference with Mr. A. F. Woods, assistant chief of the Bureau of Plant Industry, who is chairman of a committee appointed by the section of botany and horticulture of this association to formulate a scheme for courses in botany, it was ascertained that after an independent study of this matter that committee had reached substantially the same conclusions as had our committee, as far as the lines of our work coincided, and that both committees were in general accord with the scheme proposed by a committee of the Society for Plant Morphology and Physiology. Special attention is therefore invited to the report presented by Mr. Woods to the section on botany and horticulture.

The standard series of entrance requirements referred to above is as follows:

(1) Physical geography.
(2) United States history.
(3) Arithmetic, including the metric system.
(4) Algebra, to quadratics.
(5) English grammar and composition, together with the English requirements of the New England Association of Colleges and Preparatory Schools.

(6) Plane geometry.

(7) One foreign language.

(8) One of the natural sciences.

(9) Ancient, general, or English history.

The general relation of the natural-science courses to those in agriculture and other subjects may be seen in the following outline of the agricultural course in college as laid down in a previous report of this committee.

*Agricultural course in college.*[1]

| Freshmen. | | Sophomores. | | Juniors. | | Seniors. | |
|---|---|---|---|---|---|---|---|
| Subjects. | Hours. | Subjects. | Hours. | Subjects. | Hours. | Subjects. | Hours. |
| Physics | 150 | Agriculture: | | Agriculture: | | Agriculture: | |
| Chemistry | 150 | Zootech. 60<br>Agron. 90 | 150 | Agron. 50<br>Zootech. 100 | 150 | Dairying 70<br>Farm mechanics 60<br>Rural economics 60 | 190 |
| Geometry and trigonometry | 155 | Meteorology | 60 | Geology | 120 | Veterinary medicine | 180 |
| English | 120 | Agricultural chemistry | 180 | Botany | 60 | Horticulture and forestry | 180 |
| Modern language | 180 | Botany | 120 | Physiology | 180 | History and political economy | 190 |
| | | English | 80 | Zoology | 120 | Ethics | 40 |
| | | Modern language | 100 | Psychology | 60 | | |
| | | Drawing | 60 | Modern language | 60 | | |
| | 755 | | 750 | | 750 | | 780 |

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[1] A general outline of this course, without reference to its division according to years, was given in the second report of this committee. (See U. S. Dept. Agr., Office of Experiment Stations Bul. 49 and Circ. 37.) The number of hours assigned to each subject includes the time given to laboratory exercises, each of which would occupy two hours. Thus, for example, 150 hours of physics may be divided into 60 lectures or recitations, and 45 (=90 hours) laboratory exercises. Our committee has not attempted to say how the time should be divided between lectures or recitations and laboratory exercises, but presupposes that a reasonable number of laboratory exercises or practicums will be given in all the science courses.

The arrangement of the college course here suggested proceeds on the assumption that it is best for the student to devote his time largely during the first two years to language, mathematics, and the fundamental sciences, physics, chemistry, and botany. He will thus be prepared for a better understanding of the more complex sciences of agriculture, zoology, animal physiology, and veterinary medicine in the second half of his course.

The course in agriculture has been arranged with reference to taking up first in sophomore year some of the simpler topics in zootechny, such as stock judging and types of breeds, which do not require scientific knowledge, but are well calculated to arouse the interest of the student in agricultural subjects. Agronomy may then be taken up systematically and run along with the study of meteorology, agricultural chemistry and botany, and the more scientific study of zootechny may be parallel with the study of physiology and zoology. In senior year a considerable number of electives could be offered, one or more of which might be substituted for veterinary medicine, horticulture and forestry, or history and political economy, so as to enable the student to specialize in agronomy, horticulture, zootechny, dairying, farm mechanics, vegetable pathology, entomology, etc. In general, however, it is believed that the course as here outlined will be satisfactory as providing a liberal education, including systematic study of the theory and practice of agriculture, and as a good foundation for specialization in agriculture and the sciences related thereto in postgraduate courses.

## COURSES IN THE NATURAL SCIENCES.

### PHYSICS—PREPARATORY COURSE.

General laws and principles of—

- Dynamics of solids, liquids and gases,
- Heat,
- Electricity and magnetism,
- Sound,
- Light.

### PHYSICS—COLLEGE COURSE—150 HOURS.

**General constitution and properties of matter.**

- **Dynamics, or the general laws of force and the relations existing between force, mass, and velocity as applied to**
  - Solids (Mechanics).
  - Liquids (Hydrostatics).
  - Gases (Pneumatics).
- **Heat**
  - Measurement of temperature (thermometry).
  - Expansion (solids, liquids, gases).
  - Measurement of quantity of heat (calorimetry, specific heat).
  - Latent heat.
  - Fusion and solidification.
  - Evaporation and condensation.
  - Conduction.
  - Radiation.
  - Thermodynamics.
  - Relation of temperature to movements of the atmosphere.
- **Electricity and magnetism.**
  - General theories and laws.
  - Sources and production.
  - Measurement.
  - Atmospheric electricity.
  - Applications.
- **Sound and light**
  - Sound—production and propagation.
  - Light
    - Propagation.
    - Reflection.
    - Refraction
    - Polarization
    - Applications—lenses and optical instruments.
  - Color.

### GENERAL CHEMISTRY—150 HOURS.

**Properties of elements and chemical reactions.**

**Inorganic preparations.**

- **Introduction to qualitative analysis**
  - Blowpipe analysis.
  - Separation of groups.

**Introduction to organic chemistry.**

## AGRICULTURAL CHEMISTRY—180 HOURS.

- **General introduction and review**
  - Composition and properties of matter.
  - Properties and laws of combination of elements and simpler compounds.
  - Laboratory manipulations.
  - Classification of elements, equations, formulas, etc.
- **Chemistry of**
  - Air and water.
  - Soils and fertilizers.
  - Plant growth and products.
  - Animal life
    - Foods.
    - Nutrition.
    - Animal body and products.
  - Dairying.

**Introduction to analytical methods.**

## BOTANY—180 HOURS.[1]

The accompanying outline course for botany in the agricultural colleges is based very largely upon the standard elementary course recommended for adoption by the Society for Plant Morphology and Physiology, and embraces one year's work, the lectures and laboratory work required being about 180 hours. The various topics and sequence need not be strictly followed, and in many cases it will be found advisable to transfer subjects from one group to another in the sequence of teaching. Either group may be condensed, or each may be extended to cover a year's work. If 120 hours are given in the second year and 60 hours in the third year, the adjustment can be made to suit the convenience of the instructor and the facilities for instruction. Instruction in taxonomy is not provided, since the use of the manual, while desirable in itself, is not essential for an elementary course in botany. In Botany II it is recommended that the earlier groups of plants be passed over rapidly, particular attention being given to their economic features, and that progressively more time be given to the higher and more conspicuous forms. The course as a whole may be given in about 80 hours of lectures or recitations and 100 hours of practicums.

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[1] The time allowance for this course might with advantage be extended to 240 hours by taking 60 hours from physiology, which has been given a relatively liberal time allowance.

## BOTANY I.—GENERAL PRINCIPLES.

- **Anatomy and Morphology.**
  - The seed
    - Types.
    - Structures.
    - Homologous parts.
    - Food supply.
    - Germination.
  - The shoot
    - Gross anatomy.
    - Phyllotaxy.
    - Buds
      - Common forms.
      - Winter forms.
    - Tissues
      - Structure.
      - Distribution.
    - Specialized forms of stems, leaves, etc.
    - Growth, annual.
    - Shedding of bark, leaves etc.
  - The root
    - Gross anatomy of typical root.
    - Secondary roots.
    - Specialized forms.
    - Tissues
      - Structure.
      - Distribution.
  - The flower
    - Typical structure.
    - Function of parts.
    - Morphological study of several parts.
    - Construction of diagrams
      - Transverse.
      - Longitudinal.
  - The fruit
    - Structure with especial reference to changes from flower to fruit.
    - Morphological study of types.
  - The cell
    - Contents.
    - Structure.
    - Modifications.
    - Formation of tissues.
- **Physiology**
  - Rôle of water
    - Absorption.
    - Transfer.
    - Transpiration.
    - Turgidity.
    - Plasmolysis.
  - Photosynthesis
    - Rôle of chlorophyll.
    - Rôle of light.
    - Rôle of carbon dioxid.
    - Evolution of oxygen.
    - Study of starch grains.
  - Respiration
    - Rôle of oxygen.
    - Evolution of carbon dioxid.
  - Digestion
    - Action of diastase.
    - Translocation of food.
  - Irritability
    - Nature of stimulus.
    - Nature of response.
    - Geotropism.
    - Heliotropism.
    - Hydrotropism, etc.
  - Growth
    - Localization.
    - Amount of growth in seeds, stems, etc.
    - Relation to temperature, moisture, etc.
  - Reproduction
    - Fertilization.
    - Sexual.
    - Asexual.

**Ecology.—A study of plants in their reciprocal relations.**
- Modifications for special functions.
- Dissemination.
- Cross pollination.
- Light relations.
- Plant societies
  - Mesophytes.
  - Hydrophytes.
  - Halophytes.
  - Xerophytes.
  - Climbers.
  - Epiphytes.
  - Parasites.
  - Saprophytes.
  - Insectivorous plants.
  - Symbiosis.
  - Plant associations.
  - Zonal distribution.

### BOTANY II.—NATURAL HISTORY AND CLASSIFICATION.

**Classification.**
**Structure.**
**Reproduction.**
**Homologies.**
**Adaptations.**

**Types for study**
- Algæ
  - Pleurococcus.
  - Spirogyra.
  - Vaucheria.
  - Fucus.
- Fungi
  - Bacteria.
  - Yeasts.
  - Rusts.
  - Smuts.
  - Mildews.
  - Toadstools.
  - Puffballs.
- Lichens
  - Parmelia.
- Bryophytes
  - Hepatics (Marchantia or Porella).
  - Mosses.
- Pteridophytes
  - Ferns.
  - Horsetails.
  - Lycopodium.
- Gymnosperms
  - Pine.
- Angiosperms
  - Monocotyledon.
  - Dicotyledon.

### METEOROLOGY—60 HOURS.

The course here outlined assumes some knowledge of general weather changes as illustrated on the daily weather map and as recommended by the conference on geography of the National Educational Association in 1893 for the lower schools, and that the student has taken an elementary course in physics in the high school or first year in college, and especially has precise knowledge of mass, volume, density; force, inertia, velocity, rotation, centrifugal force; gravitation, gravity, weight; atom, molecule; solid, liquid, gas; expansion, heat, temperature, specific heat, latent heat.

**Definition and scope.**

- **The atmosphere (in general)**
  - Origin.
  - Composition.
  - Extent and weight.
  - Arrangement about the earth (relations to geosphere and hydrosphere).
- **Temperature**
  - Sources, nature, transmission of heat.
  - Variations.
  - Measurement.
  - Distribution over the earth.
- **Pressure**
  - General principles.
  - Measurement.
  - Distribution.
  - Relations to atmospheric circulation.
- **Circulation—general movements and local winds.**
  - Measurement.
  - Distribution.
  - Causes and modifying influence (convectional theory and effects of earth's rotation).
  - Classification.
- **Atmospheric moisture.**
  - Origin.
  - Measurement.
  - Distribution.
  - Condensation in form of
    - Dew.
    - Frost.
    - Clouds.
- **Storms**
  - Cyclones
    - Tropical.
    - Extratropical.
    - Anticyclones.
  - Thunderstorms.
  - Tornadoes.
- **Precipitation**
  - Rainfall
    - Sources.
    - Measurement.
    - Distribution.
    - Relation to atmospheric circulation.
  - Snow, hail, etc.
- **Weather**
  - Of different zones and seasons.
  - Observation and prediction.
- **Climate**
  - Of different zones, elevations, and localities.
  - Variations.

## GEOLOGY—120 HOURS.

**The earth in its relation to the solar system.**

- **Geognosy: The materials of the earth.**
  - The Atmosphere—composition, volume, and weight.
  - The Ocean—composition, volume, and weight.
  - The Solid Globe—dimensions, shape, and constitution.
    - Elements constituting rocks.
    - Minerals constituting rocks.
    - Rocks.
  - The weathering of rocks and formation of soil.
    - Principles involved.
      - Action of the atmosphere and of heat and cold.
      - Chemical action of water.
      - Mechanical action of water and ice.
      - Action of plants and animals.
    - Considerations of special cases.
      - Weathering of granite, gneiss, trappean rocks, sandstone, limestone, slate, etc.
      - Proportional amounts of various constituents removed or lost.
      - Physical manifestations of weathering — size and shape of resultant particles, and their chemical composition.
- **Dynamical Geology** --
  - Volcanoes, hot springs, and geysers.
  - Earthquakes.
  - Upheaval and depression.
  - Circulation of water in springs, rivers, and oceans.
  - Glaciers and glaciation.
  - Erosion and deposition.
  - Metamorphism.
- **Structural Geology** --
  - Architecture of the earth's crust, stratification and bedding, jointing, cleavage, mode of occurrence of rock masses.
- **Stratigraphic Geology (Historical Geology).**
  - General principles.
  - Development of life.
  - Development of continents.
- **Man as a Geological Agent.**
  - The earth as modified by human action; effects of deforestation, etc.
- **Economic Geology** ---
  - Ore deposits—occurrence and mode of deposition.
  - Ores of the metals.
  - The nonmetallic minerals.
  - Building and decorative material.
  - Road metal.
  - Mineral waters, artesian waters, etc. (hydrography).
  - Soils—surveys and mappings.
- **Physiographic Geology.**
  - Physiography—its influence on distribution and development of the human race, etc.

## PHYSIOLOGY—180 HOURS.

Physiology is the science of the functions of living tissue (here confined to animals). The main facts and theories of animal physiology apply to man and the various domesticated animals, and constitute the subject of general physiology. If preferred, a course in human physiology covering substantially the same topics may be substituted. In the agricultural college the hygiene of domesticated animals will ordinarily be taught under the separate subject of zootechny, and the same may be said for metabolism and digestion in different species of animals. Illustrative materials and simple demonstrations will be used in connection with the lectures or text-book.

**Definitions, problems, methods of study.**

**Protoplasm**
- Composition.
- Functions
  - Metabolism.
  - Change of form.
  - Movements.
  - Development of energy.
  - Irritability.
  - Reproduction.

**Physical and chemical conditions of animal life.**
**Mechanics of animal life.**

**Digestion**
- Saliva.
- Gastric juice.
- Bile.
- Pancreatic juice.
- Intestinal juices.
- Lacteals and lymphatics.
- Mechanism of digestion.
- Absorption.
- Assimilation.
- Distribution of the products of digestion.

**Blood**
- Composition and elements.
- Distribution in the body.

**Respiration**
- Respiratory changes in the blood and tissues.
- Oxygen, carbon dioxid, and nitrogen in the blood.
- Mechanics of respiratory movements.
- Nervous control of respiration.
- Relations of circulatory and respiratory systems.

**Excretion**
- Composition and excretion of urine.
- Excretion of sweat and nature and amount of perspiration.
- Feces.

**Circulation**
- Structure of heart, arteries, veins, and capillaries as related to their functions.
- Course of circulation.
- Mechanics of circulation.
- Nervous control.
- Blood pressure.
- Pulse.
- Fluctuations in quantity of blood.

**Muscular action**
- Simple muscular contraction.
- Relation of nervous and muscular systems.
- Changes in muscles during contraction
  - Chemical.
  - Thermal.
  - Electrical.
- Conditions which determine muscular irritability and action.

- **Nervous system**
  - Brain
    - Structure and anatomy of brain as related to nervous functions.
    - Localization of motor and sensory areas in the brain.
    - Conditions of cerebral action.
  - Spinal cord
    - Structure and functions.
    - Reflex action.
  - Special senses
    - Sight
      - Structure and optical principles of the eye.
      - Function of various parts of the eye.
    - Hearing — Structure and functions of the ear.
    - Smelling — Structure and functions of the nasal fossæ.
    - Taste — Functions of various organs concerned in this sense.
- **Reproduction**
  - Function of various organs.
  - Nutrition of the fetus.
- **Comparative Physiology.**
  - Comparative study of various functions in animals and man, e. g., digestion in man, horse, cow, sheep, hog, and chicken.

### ZOOLOGY—120 HOURS.

Zoology is the science of animal life in its broadest sense. In agricultural colleges the subject matter of zoological courses is perhaps best largely confined to a study of the anatomy, habits, distribution, and natural enemies of the important injurious and beneficial species. The special economic aspects of domesticated mammals and birds would naturally be taught under zootechny, while the general subject of the interrelations of animals to man comes under the subject of zoology. An outline course in economic entomology is provided in connection with the course in zoology. The course, as a whole, provides for forty to forty-five lectures, and about eighty practicums (of two hours each).

**Definition and general orientation.**

- **Classification**
  - Protozoa.
  - Cœlenterata.
  - Echinodermata.
  - Mollusca.
  - Vermes.
  - Arthropoda.
  - Bryozoa.
  - Brachiopoda.
  - Tunicata.
  - Vertebrata
    - Fishes.
    - Amphibians.
    - Reptiles.
    - Birds.
    - Mammals.
- **Gross anatomy**
  - Discussion and study of types of various groups.
  - Comparative morphology of organs in various groups.
  - Anatomical evidences of relationship and evolution.

- **Microscopical anatomy**
  - Simple cell.
  - Muscle cell.
  - Gland cell.
  - Bone cell.
  - Nerve cell.
  - Various forms of tissue.
- **Development, embryology**
  - Fertilization.
  - Segmentation of egg.
  - Germinal layers.
  - Origin of organs.
  - Study of types.
  - Embryological evidences of relationship.
- **Distribution**
  - Means of distribution.
  - Laws of distribution.
  - Natural barriers and life zones.
- **Economic aspects of animal life.**
  - Feeding habits of various groups.
  - Interrelation of various groups.
  - Usefulness of animals and economic animal products.
  - Direct relationship of animals to agriculture.
    - Birds.
    - Mammals.
    - Insects (entomology)
      - Classification.
      - Habits.
      - Life history.
      - Useful species.
      - Injurious species.
      - Means of repression.
        - Parasitic insects.
        - Predaceous insects.
        - Fungus diseases.
        - Cultural methods.
        - Mechanical methods.
          - Barriers.
          - Tar bands.
          - Traps.
          - Ditches, etc.
          - Heat.
          - Cold.
        - Chemical methods.
          - Dry insecticides.
          - Spraying
            - Contact insecticides.
            - Poisons.
            - Spraying calendar.

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